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PROGRESS REPORT ON KILN-DRYING PREFROZEN WALNUT GUNSTOCKS--TECHNIQUES AND RESULTS

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Black walnut, tanoak, and black cherry are three American hardwoods that are significantly easier to dry when prefrozen (1,2,3). Black walnut 4/4 and thicker has been consistently frozen without damage at temperatures down to -310° F. The only problems ever reported of freezing breakage in hardwoods has been in Eucalyptus regnans, when green wood frozen in liquid air at -317° F. cracked severely. However, prefreezing the same material at -5° and -109° F. was satisfactory (5). Whether the breakage was due to unusually high moisture content or thermal stresses is not known.

Shrinkage reduction depends partly on the prefreezing temperature. In several black walnut tests the optimum temperature was between -10° and -110° F. (1,2,4). It appears that the most practical freezing temperature for black walnut is at -10°. This is within the normal range of mechanical freezers, and it gives a satisfactory reduction in shrinkage, collapse, and honeycomb.

There is evidence that the drying rate of some hardwoods early in the kiln-drying period is increased by prefreezing. Black walnut prefrozen after air-drying to 28 percent moisture content dried down to 15 percent faster than did air-dried controls (3). Similarly, black walnut frozen at -10° F. and -100° F. in the green condition kiln-dried to 46 percent moisture content faster than did unfrozen matched material (2).

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A logical industrial pilot application of prefreezing is the drying of thick, refractory black walnut gunstock blanks, which are typically dried in large package-loaded kilns. Even though mild schedules ranging between 100 to 200 days are used, companies report 2-1/2 percent defectives caused by drying in addition to 2-1/2 percent mill defectives that get into the kilns.

We asked the American Walnut Company, Kansas City, Missouri, to cooperate in a pilot test of the effectiveness of prefreezing 2-1/4-inch-thick stock blanks. They agreed to loan us 1,000 blanks. Our objective was to accelerate drying 50 percent compared to conventional drying times and keep the defective rate down.

Prefreezing Techniques Used

The green blanks were processed at the USDA Forest Products Laboratory in Madison, Wisconsin. They first were measured for thickness and width at a marked point and weighed. Many of the blanks, which had been dipped in hot wax at the factory, exhibited incomplete or damaged end-coating when received. These were recoated with an asphalt roofing compound containing asbestos particles.

From the 600 blanks selected at random for prefreezing, 14 were fitted with thermocouples for use as check blanks. All 600 then were palletized, using stickers to separate the courses, and placed in a freezer for 24 hours at -15° F. Temperatures of the check blanks, which had been inserted in the center of the packages, ranged between -4° F. and -12° F.; most were -9° F. After these blanks had thawed, inspection showed that none had been damaged by prefreezing.

The 600 prefrozen and 400 control blanks were intermixed and stickered on kiln trucks to a 4-foot width. One sticker at each end supported the blanks. Thirty of the wettest and heaviest prefrozen

blanks and 20 comparable blanks from the unfrozen blanks were used as kiln samples. These kiln samples were evenly distributed on each side of a 12-course high charge. No top load was added.

We used a modified T3-D4 kiln schedule. A scaled-down commercial-type 3,000 board foot capacity track kiln, which had been installed at the Laboratory by the USDA Forest Service's State and Private Forestry, was used to dry the 1,000 blanks. This is slightly more severe than the T3-D4 schedule shown in the Dry Kiln Operator's Manual (Fig. 1). We used air speeds through the load of 350 fpm to increase the drying rate. Drying time was 103 days plus 1 day of conditioning. We dried until the driest sample reached 5 percent moisture content, after which we equalized at 5 percent equilibrium moisture content until the wettest sample reached 7 percent. Conditioning at 11 percent using the maximum dry bulb temperature of 155° F. completed the drying.

As each gunstock blank was removed from the kiln, it was remeasured, reweighed, inspected, and metered for moisture content.

Results and Comment

After 103 days in the kiln, the blanks were essentially stress free as indicated by samples cut before and after conditioning. Their moisture contents, which were recorded using a surface contact meter, ranged between 5 and 7 percent. There were no differences in the moisture contents nor in the drying rates during any phase of the drying between the prefrozen and unfrozen blanks.

However, there were shrinkage differences between the prefrozen and unfrozen samples, but they were less than those observed in earlier tests using 2- by 4-inch black walnut (Table 1). Nevertheless, the differences were significant because any reduction in shrinkage reduces the stresses that cause drying defects.

The defects that showed up after drying and machining of the blanks were all carefully examined. After four inspections, which were far more critical than would normally be conducted, we were certain we saw all the defects. As shown in Table 2, only about 1-1/2 percent of the defects were mill defects (knots, the pith, miscuts), which was interesting because the industry average is about 2-1/2 percent. We may have run 1 percent lower than industry because the material for the test was more carefully selected than is material for typical runs.

Our accelerated schedule increased the drying defects (Table 2), but we had a problem with end-coating failures that confounds the results. The most common defect was honeycomb in both the prefrozen and unfrozen blanks. It is significant that only two of the honeycombed blanks (both prefrozen) had been given the additional end coat. All the other honeycombed blanks had only been given the wax end coat at the factory, all of which showed visible evidence of end-coating failure. Many of the nondefective blanks that had been given the additional end coat had intact blisters of the coating. This clearly indicates that the original coating allowed moisture vapor to escape, but that the additional coating entrapped it. Therefore, it is possible that the failure of the end-coating prevented differences in honeycombing between the prefrozen and unfrozen blanks from developing. If the end-coating had been satisfactory, we think the prefreezing treatment would have resulted in less honeycombing in the stocks.

The second greatest defect group was cracks, checks, splits, and shake. In the prefrozen group of stocks, 1.50 percent had such defects; in the unfrozen stocks, 4.75 percent had such defects. This was significant and accounted for most of the overall difference between the groups (Table 2).

Warp could have been largely avoided if we had used a sticker at the mid-length of each stock during drying. Furthermore, a higher load and weights on the load would have helped. The unfrozen stocks showed more warp as expected.

The overall effectiveness of the prefreezing can be expressed as the reduction in amount of defectives (29.2 percent) in the unfrozen samples (Table 2). This could be increased greatly if a real difference in honeycombing could be measured.

Looking at the whole picture, it is reasonable to consider the trade-off that is possible for the industry. If prefreezing and drying in 10~~3~~4 days is possible with only a 5 percent increase in honeycomb, collapse, checking, cracking, splitting, and shake, what is the cost vs. the benefits? Time, fuel, labor, inventories, and fixed costs can obviously be reduced. Against this must be considered the added cost of prefreezing and the increase in defectives to 7-1/2 percent from 2-1/2 percent. If honeycomb can be eliminated by a good end-coating, it may be possible to achieve such reductions in drying times and still keep the total defectives at a reasonable level.

We still need to develop better end-coating, we need to test faster schedules, and we need to study the effectiveness of using prefreezing on other difficult-to-dry products, such as turning squares.

Table 1.--SHRINKAGES OF KILN-DRIED BLACK WALNUT GUNSTOCKS

Type of shrinkage	Prefrozen	Unfrozen	Shrinkage reduction (%)
	Green dimensions (%)		
Thickness	5.59	5.77	3.1
Width	5.20	5.48	5.1
Volumetric	10.47	10.94	4.3

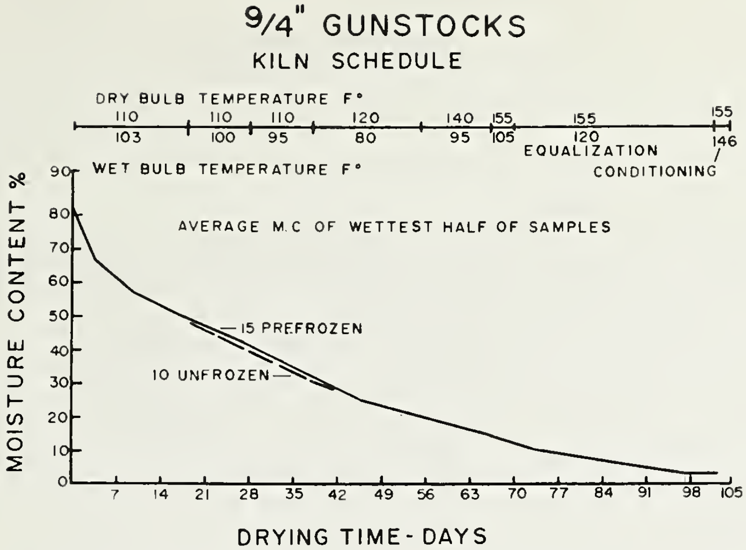

Figure 1.--Kiln-drying schedule and drying curve of prefrozen and unfrozen black walnut gunstock blanks. The drying curves of all the blanks coincide except for the brief period indicated by the broken line.

Table 2.--GUNSTOCK BLANKS FOUND DEFECTIVE AFTER DRYING AND ROUGH MILLING

Defect	In 600 prefrozen			In 400 unfrozen		
	No.	%	% increase[1]	No.	%	% increase
Mill defects:						
Knots, pith	8	1.33		6	1.50	
Drying defects:						
Honeycomb	36	6.00		23	5.75	
Collapse	2	0.33	5.33	1	0.25	8.25
Cracking, checking, splitting, shake	9	1.50		19	4.75	
Warp	5	0.83		6	1.50	
Total drying	52	8.67		49	12.25	
All	60	10.00		55	13.75	

Effectiveness of prefreezing in reducing defects during accelerated

$$\text{drying} = \frac{12.25 - 8.67}{12.25} \times 100 = 29.2 \text{ percent.}$$

[1] Assumes industry presently gets 2-1/2 percent defectives in the same categories using 180- to 200-day kiln-drying schedule.

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